[Designation of Document] Description

[Title of Invention] AMPLIFIER AND COMMUNICATION APPARATUS

[Technical Field]

[0001]

The present invention relates to an amplifier and a communication apparatus which are used for transmission and reception during wireless communication, and particularly to an amplifier and a communication apparatus which are applied to, for example, UWB (ultra-wideband) communication and perform voltage amplification of a high frequency component of a received signal.

[0002]

More specifically, the present invention relates to an amplifier and a communication apparatus which collectively perform amplification in a wide frequency bandwidth used in UWB communication, and particularly to a wide-band amplifier and a communication apparatus having a flat amplification characteristic over a wide frequency bandwidth, being prevented from degrading due to parasitic capacitance, and being short in group delay time.

[Background Art]

[0003]

Wireless LANs are receiving attention as systems which release users from the LAN wiring required in wired methods. According to wireless LANs, since almost all wired cables can be omitted in work spaces such as offices, communication terminals such as personal computers (PCs) can be comparatively easily moved. In recent years, as wireless LAN systems have increased in speed and decreased in price, demand for wireless LAN systems have remarkably increased. In recent years,

consideration is particularly given to installation of personal area networks (PANs) in order to construct a small-scale wireless network and perform information communication among a plurality of personal electronic devices.

[0004]

For example, a method called ultra-wideband (UWB) communication, which performs wireless communication by using an extremely wide frequency bandwidth, is recently receiving attention as a wireless communication system which realizes short-distance ultra-high-speed transmission, and such method is expected to be put to practical use. The IEEE802. 15. 3 committee and the like have presently proposed a data transfer method based on a packet structure containing preambles, as an access control method for ultra-wideband communication.

[0005]

In UWB communication, modulation methods such as DS-SS and OFDM are considered. According the DS-SS method, during transmission, an information signal is multiplied by a random code sequence called PN (Pseudo Noise) code to directly spread (DS: Direct Spread) the occupied bandwidth, and on a reception side, the received spread information signal is reproduced into the information signal by being inversely spread by being multiplied by the PN code. The DS-SS method makes it possible to realize high-speed data transfer by performing transmission and reception in a spread ultra-high frequency bandwidth of, for example, 3 GHz to 10 GHz.

[0006]

According to the OFDM (Orthogonal Frequency Division Multiplexing) method, the frequency of each carrier is set

so that each carrier is orthogonal with every other carrier in a symbol duration, and during transfer of information, plural pieces of data are allocated to the respective carriers and modulation is performed on the amplitude and phase of each of the carriers, and inverse FFT is performed on the plural carriers to convert each of the carriers into a signal on the time axis with orthogonality on the frequency axis being maintained, and the signal on the time axis is transmitted. During reception, FFT is performed to convert the signal on the time axis into a signal on the frequency axis and the respective carriers are subjected to demodulation corresponding to their modulation methods to reproduce the information transmitted by the original serial signal. Since transmit data are transmitted in the state of being distributed to a plurality of carriers of different frequencies, the bandwidth of each of the carriers is narrowed narrow and becomes resistible to frequency selective fading.

[0007]

In wireless communication equipment, during reception of wireless signals, it is general practice to perform voltage amplification on received signals. For example, in the above-mentioned ultra-wideband communication, voltage amplification is performed on a high frequency component by a low noise amplifier (LNA). In this case, it is desired that voltage amplification is collectively performed in a wide frequency bandwidth extending over a 2-GHz range of 3 GHz to 5 GHz which is used in UWB.

[0008]

Wide-band amplifiers can be generally constructed by a combination of an amplifier device made of MOS-FETs (Metal Oxide Semiconductor-Field Effect Transistors), bipolar

transistors or the like, and a band-pass filter (refer to, for example, Non-Patent Document 1).

[0009]

Fig. 8 shows the construction of a wide-band amplifier constructed by a combination of an amplifier device and a first-order band-pass filter (BPF) (refer to, for example, Non-Patent Document 2).

[0010]

As shown, the wide-band amplifier is constructed so that a first-order band-pass filter made of an LC parallel resonant circuit made of a parallel coil Lp 103, a parallel capacitor Cp 104 and a resistor RL 105 is provided as a load in parallel with the drain and the source of an amplifier device 102 constructed with MOS-FETs or bipolar transistors.

[0011]

In Fig. 8, reference numeral 101 denotes an input terminal of the wide-band amplifier, and reference numeral 108 denotes an output terminal of the wide-band amplifier, and the amplifier device 102 operates as a voltage-controlled current source. Specifically, a voltage V1 at the input terminal 101 is applied to the gate of the amplifier device 102, and the amplifier device outputs a current of gm times the gate voltage V1 in the direction indicated by an arrow in Fig. 8. The voltage provided at the output terminal 108 at this time is denoted by V2.

[0012]

The transfer function H(s) of the wide-band amplifier shown in Fig. 8 is expressed by the following formula:

[0013]

[Formula 1]

$$H(s) = \frac{-s \cdot Lp \cdot RL \cdot gm}{s^2 \cdot Lp \cdot Cp \cdot RL + s \cdot Lp + RL}$$

[0014]

Fig. 9 shows a pole-zero map in the s-plane of the wide-band amplifier shown in Fig. 8. In Fig. 9, the symbol "o" denotes a zero, and the symbol "×" denotes a pole. On the s-plane, poles are located at points where the denominator of the transfer function H(s) is 0, while zeroes are located at points where the numerator of the transfer function H(s) is 0. In the shown example, a zero is located at the center of the s-plane, and the number of poles that corresponds to the order of the band-pass filter appear on one side of the s-plane.

[0015]

Figs. 10 and 11 respectively show a transfer characteristic example and a group delay characteristic of the wide-band amplifier shown in Fig. 8. Each of the characteristics is normalized as gm × RL = 1 with a center frequency of 4 GHz. A cross section obtained on the imaginary axis when the band-pass filter has a transfer characteristic of $-\infty$ at the zero and a transfer characteristic of $+\infty$ at each of the poles on the s-plane corresponds to the transfer characteristic of the band-pass filter. The band-pass filter in which the parameter of the LCR parallel resonant circuit (i.e., the s-plane transfer characteristic shown in Fig. 9) is set to flatten the passband (for example, 3 GHz to 5 GHz) is called a Butterworth filter, and such transfer characteristic is called a Butterworth character.

[0016]

However, as can also be seen from Figs. 10 and 11, in

the wide-band amplifier constructed using the first-order band-pass filter made of the LCR parallel resonant circuit as a load for the amplifier device, the following problems arise.

[0017]

(1) The frequency characteristic is a single peak characteristic and does not have flatness sufficient to be used in a wide bandwidth. This problem also depends on the fact that the first-order band-pass filter merely has the number of poles that corresponds to the order, i.e., one pole, on one side.

[0018]

(2) The amplifier has a comparatively simple construction as shown in Fig. 8; nevertheless the wide-band amplifier has group delay time.

[0019]

In this construction, if the bandwidth over which the flatness is to be maintained is to be widened, the inductance Lp of the coil 103 must be increased, or the resistance value RL of the resistor 105 must be decreased. However, if the inductance Lp is increased, since the self-resonant frequency is low, the amplifier is not suitable for operation at high frequencies. In addition, if the resistance value RL is decreased, the amplifier decreases in gain.

[0020]

Fig. 12 shows the construction of a wide-band amplifier constructed by a combination of an amplifier device and a second-order band-pass filter (BPF).

[0021]

As shown, the wide-band amplifier is constructed so that a second-order band-pass filter is provided as a load in

parallel with the drain and the source of the amplifier device 102 constructed with MOS-FETs or bipolar transistors. The second-order band-pass filter is constructed with an LC parallel resonant circuit made of the parallel coil Lp 103 and the parallel capacitor Cp 104, an LC series resonant circuit made of a series coil Ls 107 and a series capacitor Cs 106, and the resistor RL 105.

[0022]

Fig. 12, reference numeral 101 denotes an input terminal of the wide-band amplifier, and reference numeral 108 denotes an output terminal of the wide-band amplifier, and the amplifier device 102 operates as a voltage-controlled current source. Specifically, a voltage V1 at the input terminal 101 is applied to the gate of the amplifier device 102, and the amplifier device outputs a current of gm times the gate voltage V1 in the direction indicated by an arrow in Fig. 12. The voltage provided at the output terminal 108 at this time is denoted by V2.

[0023]

The transfer function H(s) of the wide-band amplifier shown in Fig. 12 is expressed by the following formula:

[0024]

[Formula 2]

$$H(s) = \frac{-s^2 \cdot Lp \cdot Cs \cdot RL \cdot gm}{s^4 \cdot Lp \cdot Ls \cdot Cp \cdot Cs + s^3 \cdot Lp \cdot Cp \cdot Cs \cdot RL + s^2 \cdot (Lp \cdot Cp + Ls \cdot Cs + Lp \cdot Cs) + s \cdot Cs \cdot RL + 1}$$

[0025]

Fig. 13 shows a pole-zero map in the s-plane of the wide-band amplifier shown in Fig. 12. In Fig. 13, the symbol "o" denotes a zero, and the symbol "x" denotes a pole. On the s-plane, poles are located at points where the

denominator of the transfer function H(s) is 0, while a zero is located at a point where the numerator of the transfer function H(s) is 0. In the shown example , a zero is located at the center of the s-plane, and two poles corresponding to the order of the band-pass filter appear on one side of the s-plane. In this wide-band amplifier, the Butterworth character is adopted in order to flatten the passband (for example, 3 GHz to 5 GHz).

[0026]

Figs. 14 and 15 respectively show a transfer characteristic example and a group delay characteristic of the wide-band amplifier shown in Fig. 12. Each of the characteristics is normalized as gm × RL = 1 with a center frequency of 4 GHz.

[0027]

In the wide-band amplifier constructed using the second-order band-pass filter as a load for the amplifier device, as can also be seen from a comparison of Figs. 10 and 14, the characteristic flatness in the passband is improved, but the following problems arise.

[0028]

(1) The wide-band amplifier shown in Fig. 12 is long in group delay time compared to Fig. 11, and is not suitable for a voltage-feedback amplifier circuit. This problem depends on the fact that the series coil Ls 107 and the series capacitor Cs 106 are inserted in series between the output terminal of the amplifier device 102 and the output terminal 108 of the amplifier and the resonance of this LC circuit becomes a main cause of delay. (In the case of the amplifier shown in Fig. 8, since the output terminal of the amplifier device 102 serves as the output terminal 108 of the amplifier, the

problem of group delay does not arise.)

[0029]

(2) In the case where a subsequent-stage circuit (such as a down-converter, an AGC or an A/D converter) is connected to the output terminal 108 of the amplifier, the circuit acts as parasitic capacitance for the amplifier, but since a capacitance element does not exist between the output terminal of the amplifier and GND, the parasitic capacitance added to the output terminal cannot be absorbed as part of constants and the frequency characteristic degrades.

[0030]

In the example shown in Fig. 12, since the amplifier is constructed so that the series capacitor Cs 106 and the parasitic capacitance are connected in series, it is difficult to eliminate the influence of parasitic capacitance. On the other hand, in the example shown in Fig. 8, the parallel capacitor Cp and the parasitic capacitance are connected in parallel instead of the construction in which the capacitor is connected in series with the parasitic capacitance, so that it is possible to easily eliminate the problem of parasitic capacitance by decreasing the capacitance of the parallel capacitor Cp 104.

[0031]

[Non-Patent Document 1]

Ken Yanagisawa and Noriyoshi Kamiya, "Theory and Design of Filter", (Akiba Shuppan, 1986)

[Non-Patent Document 2]

Guillermo Gonzales, "Microwave Transistor Amplifiers Analysis and Design", (pp. 170-172, Prentice Hall, 1984)

[Disclosure of the Invention]

[Problems that the Invention is to solve]

[0032]

An object of the present invention is to provide a superior amplifier and communication apparatus both of which can be used in UWB communication and can collectively perform amplification in a wide frequency bandwidth.

[0033]

Another object of the present invention is to provide a superior amplifier and communication apparatus having a flat amplification characteristic over a wide frequency bandwidth, being prevented from degrading due to parasitic capacitance, and being short in group delay time.

[Means for Solving the Problems]

The present invention has been made in view of the above-mentioned problems, and provides an amplifier characterized by including an amplifier device and a band-pass filter provided as a load for the amplifier device and having an s-plane in which a plurality of poles are provided and zeros are provided between the poles.

[0035]

A cross section obtained on the imaginary axis when the band-pass filter has a transfer characteristic of $-\infty$ at each of the zeros and a transfer characteristic of $+\infty$ at each of the poles on the s-plane corresponds to the transfer characteristic. From this fact, in accordance with the wide-band amplifier according to the present invention, the characteristic flatness in the passband is improved by the interaction of each of the zeros located at the respective locations other than the origin and the neighboring poles. Specifically, a wide-band characteristic according to the present embodiment is comparable to a characteristic flatness obtainable when a second-order band-pass filter is provided

as a load for an amplifier device.

[0036]

In this construction, the band-pass filter serving as a load for the current output amplifier device is made of an LC parallel resonant circuit and an LCR series resonant circuit provided in parallel with the amplifier device.

[0037]

The band-pass filter in this case does not have a capacitor provided in series with the output terminal of the amplifier, so that the problem of group delay does not arise, as in the case where a first-order band-pass filter is applied as a load for the amplifier device.

[0038]

In addition, in this case, the amplifier has a circuit construction in which an inductance and a capacitor are not provided in series between the output terminal of the amplifier device and the output terminal of the amplifier. Accordingly, a capacitance element exists between the output terminal of the amplifier and GND, so that even if a subsequent-stage circuit (such as a down-converter, an AGC or an A/D converter) is connected to the output terminal of the amplifier, it is possible to prevent degradation of the frequency characteristic by absorbing, as part of constants, parasitic capacitance added to the output terminal.

[0039]

In addition, if the amplifier according to the present invention is combined with a common-gate circuit and a cascode circuit, a wide-band amplifier having input matching widened in bandwidth can be realized.

[0040]

Otherwise, if the amplifier according to the present

invention is combined with a common-source circuit and a cascode circuit, a wide-band amplifier having input matching widened in bandwidth can be realized.

[Advantage of the Invention]

[0041]

According to the present invention, since a constant transfer characteristic can be obtained over a wide bandwidth, a wide-band amplifier can be constructed.

[0042]

In addition, according to the present invention, since group delay time is short, a wide-band amplifier using a voltage feedback amplifier can be constructed.

[0043]

In addition, according to the present invention, since a parallel capacitor is provided between an output terminal and GND, even if parasitic capacitance is added to the output terminal, the parasitic capacitance can be absorbed as part of constants, so that degradation of the frequency characteristic can be prevented.

[0044]

In addition, according to the present invention, by combining with a common-gate circuit and a cascode circuit, it is possible to construct a high-gain wide-band amplifier widened in input impedance matching.

[0045]

In addition, according to the present invention, by combining with a common-source circuit and a cascode circuit and a voltage feedback circuit, it is possible to construct a high-gain wide-band amplifier widened in input impedance matching.

[0046]

Other objects and advantages of the present invention will become apparent from the following far more detailed description of an embodiment of the present invention, taken in conjunction with the accompanying drawings.

[Best Mode for Carrying Out the Invention]

[0047]

An embodiment of the present invention will be described below in detail with reference to the accompanying drawings.

[0048]

Fig. 1 shows the construction of a wide-band amplifier according to one embodiment of the present invention. This wide-band amplifier is schematically constructed by a combination of an amplifier device made of MOSFETs, bipolar transistors or the like and a band-pass filter.

[0049]

More specifically, the wide-band amplifier is constructed so that an LC parallel resonant circuit which is made of a parallel coil Lp 103 and a parallel capacitor Cp 104 and an LCR series resonant circuit which is made of a series coil Ls 107, a series capacitor Cs 106 and a resistor RL 105 are provided as a load in parallel with the drain and the source of a current output type of amplifier device 102.

[0050]

In Fig. 1, reference numeral 101 denotes an input terminal of the wide-band amplifier, and reference numeral 108 denotes an output terminal of the wide-band amplifier, and the amplifier device 102 operates as a voltage-controlled current source. Specifically, a voltage V1 at the input terminal 101 is applied to the gate of the amplifier device 102, and the amplifier device outputs a current of gm times the gate voltage V1 in the direction indicated by an arrow

in Fig. 1. The voltage provided at the output terminal 108 at this time is denoted by V2.

[0051]

The transfer function H(s) of the wide-band amplifier shown in Fig. 1 is expressed by the following formula:

[0052]

[Formula 3]

$$H(s) = \frac{-\left(s^3 \cdot Lp \cdot Ls \cdot Cs + s^2 \cdot Lp \cdot Cs \cdot RL \cdot gm + s \cdot Lp \cdot gm\right)}{s^4 \cdot Lp \cdot Ls \cdot Cp \cdot Cs + s^3 \cdot Lp \cdot Cp \cdot Cs \cdot RL + s^2 \cdot (Lp \cdot Cp + Ls \cdot Cs + Lp \cdot Cs) + s \cdot Cs \cdot RL + 1}$$

[0053]

Fig. 2 shows a pole-zero map in the s-plane of the wide-band amplifier shown in Fig. 1. In Fig. 2, the symbol "o" denotes a zero, and the symbol "x" denotes a pole. In this wide-band amplifier, the Butterworth character is adopted in order to flatten the passband (for example, 3 GHz to 5 GHz). Figs. 3 and 4 respectively show a transfer characteristic example and a group delay characteristic of the wide-band amplifier shown in Fig. 1. Each of the characteristics is normalized as $gm \times RL = 1$ with a center frequency of 4 GHz.

[0054]

On the s-plane, poles are located at points where the denominator of the transfer function H(s) is 0, while zeroes are located at points where the numerator of the transfer function H(s) is 0. On the s-plane shown in Fig. 2, a zero is located at the center of the s-plane, and two poles corresponding to the order of the band-pass filter appear on one side of the s-plane. Furthermore, in the present embodiment, zeroes are provided between the two poles at locations other than the origin owing to the provision of the LCR series resonant circuit made of the series coil Ls, the series capacitor Cs and the resistor RL.

[0055]

A cross section obtained on the imaginary axis when the band-pass filter has a transfer characteristic of $-\infty$ at each of the zeros and a transfer characteristic of $+\infty$ at each of the poles on the s-plane corresponds to the transfer characteristic. From this fact, the characteristic flatness in the passband is improved by the interaction of each of the zeros located at the respective locations other than the origin and the neighboring poles. Specifically, a wide-band characteristic according to the present embodiment is comparable to a transfer characteristic (refer to Fig. 14) obtainable when a second-order band-pass filter is provided as a load for an amplifier device (refer to Fig. 12).

[0056]

In the case of the wide-band amplifier according to the present embodiment, the output terminal of the amplifier device 102 serves as the output terminal 108 of the amplifier, so that the problem of group delay time does not occur, similar to the case where a first-order band-pass filter is applied as a load for an amplifier device (refer to Fig. 8). This fact can also be understood from a comparison between Figs. 4 and 11.

[0057]

In the case of the wide-band amplifier according to the present embodiment, as can be seen from Fig. 1, both of the parallel capacitor 104 and the series capacitor 106 are provided in parallel with the output terminal. Specifically, a capacitance element exists between the output terminal of the amplifier and GND, so that even if a subsequent-stage circuit (such as a down-converter, an AGC or an A/D converter) is connected to the output terminal 108 of the amplifier, it

is possible to prevent degradation of the frequency characteristic by absorbing, as part of constants, parasitic capacitance added to the output terminal.

[0058]

Fig. 5 shows a construction example in which a common-gate cascode amplifier is applied as a current output amplifier device in the wide-band amplifier shown in Fig. 1.

[0059]

The input terminal 101 is connected to the source of a MOS-FET 201 so that an input signal is applied thereto. A capacitor 204 is connected between the gate of the MOS-FET 201 and GND so that the gate of the MOS-FET 201 is connected to AC ground. A resistor 202 is connected between the gate of the MOS-FET 201 and a bias terminal 203 so that a predetermined gate voltage is supplied to the MOS-FET 201. The source of a MOS-FET 301 is connected to the drain of the MOS-FET 201 so as to construct a cascode circuit.

[0060]

A capacitor 302 is connected between the gate of the MOS-FET 301 and GND so that the gate of the MOS-FET 301 is connected to AC ground. The gate of the MOS-FET 301 is connected to a bias terminal 303 so that a predetermined gate voltage is applied to the gate.

[0061]

Reference numerals 103 and 104 respectively denote a parallel inductor Lp and a parallel capacitor Cp which constitute an LC parallel resonant circuit. Reference numerals 107, 106 and 105 respectively denote a series inductor Ls, a series capacitor Cs and a resistor RL which constitute an LCR series resonant circuit. These LC parallel resonant circuit and LCR series resonant circuit are provided in

parallel as a load for the amplifier device. Reference numeral 108 denotes an output terminal.

[0062]

Since the MOS-FET 201 is gate-grounded (the source serves as an input), the input impedance is originally low and the bandwidth of impedance matching can be widened, so that good antenna matching can be obtained. In addition, since the gate width W of the cascode-connected MOS-FET 301 can be set independently of the gate width W of the MOS-FET 201, the shown construction example is suitable for increasing the gate width W of the MOS-FET 201 to obtain high gain. Furthermore, the output circuit of the present invention makes it possible to obtain constant voltage gain over a wide bandwidth.

[0063]

Fig. 6 shows a construction example in which a common-source cascode amplifier with voltage feedback is applied as a current output amplifier device in the wide-band amplifier shown in Fig. 1.

[0064]

The input terminal 101 is connected to the gate of the MOS-FET 201 so that an input signal is applied thereto. The source of the MOS-FET 201 is connected to GND. The source of the MOS-FET 301 is connected to the drain of the MOS-FET 201 so as to construct a cascode circuit.

[0065]

The capacitor 302 is connected between the gate of the MOS-FET 301 and GND so that the gate of the MOS-FET 301 is connected to AC ground. The gate of the MOS-FET 301 is connected to the bias terminal 303 so that a predetermined gate voltage is applied to the gate.

[0066]

A capacitor 401 is connected between the drain of the MOS-FET 301 and a resistor 402 so as to cut off direct current along the path of voltage feedback. The resistor 402 is connected between the capacitor 401 and the gate of the MOS-FET 201 so as to construct a feedback path for voltage feedback. The resistor 202 is connected between the resistor 402 and the bias terminal 203 so that a predetermined gate voltage is supplied to the MOS-FET 201.

[0067]

Reference numerals 103 and 104 respectively denote a parallel inductor Lp and a parallel capacitor Cp which constitute an LC parallel resonant circuit. Reference numerals 107, 106 and 105 respectively denote a series inductor Ls, a series capacitor Cs and a resistor RL which constitute an LCR series resonant circuit. These LC parallel resonant circuit and LCR series resonant circuit are provided in parallel as a load for the amplifier device. Reference numeral 108 denotes an output terminal.

[0068]

In this case, since the gate is an input, impedance becomes high, but owing to the voltage feedback formed by the connection between the capacitor 401 and the resistor 402, the input impedance can be lowered to widen the bandwidth of impedance matching, thereby realizing antenna matching. In addition, since the MOS-FET 301 is cascode-connected, the shown construction is suitable for decreasing the mirror capacitance between the drain and the gate of the MOS-FET 201 to increase the gain thereof. Furthermore, the output circuit of the present invention makes it possible to obtain constant voltage gain over a wide bandwidth.

[0069]

Finally, the construction of a wireless communication apparatus in which the wide-band amplifier according to the present embodiment is applied to an LNA will be described with reference to Fig. 7.

[0070]

A wireless communication apparatus 10 performs UWB communication which carries out wireless communication by using, for example, an extremely wide frequency bandwidth. The shown wireless communication apparatus 10 is provided with a transmitting/receiving antenna 11 and a band-pass filter 12, and is branched into a reception line and a transmission line via a transmission/reception switch 13.

[0071]

The reception line is constructed with a low noise amplifier (LNA) 14 which amplifies the voltage of a received signal, a down-converter 15 which down-converts the voltage-amplified received signal by frequency conversion, an automatic gain controller (AGC) 16, an analog-digital converter 17, and a signal processing circuit 18 which performs digital signal processing of received data.

[0072]

In this construction, if the wide-band amplifier shown in Fig. 1 is used as the low noise amplifier 14, voltage amplification can be collectively effected in a wide frequency bandwidth. In this case, since group delay time is short, it is possible to construct a wide-band amplifier using an amplifier with voltage feedback. In addition, even if a circuit at a stage subsequent to the down-converter 15 acts as parasitic capacitance, since the parallel capacitor is provided between the output terminal and GND, the parasitic capacitance added to the output terminal can be absorbed as

part of constants, so that degradation of the frequency characteristic can be prevented (as mentioned previously).

[0073]

On the other hand, the transmission line is constructed with a digital signal processing circuit 21 which perform signal processing of transmit data, a digital-analog converter 22 which converts the transmit data into an analog signal, an up-converter 23 which up-converts the analog transmit signal by frequency conversion, and a power amplifier (PA) 24 which amplifies the power of the up-converted transmit signal.

[Industrial Applicability]

[0074]

The present invention has been described above in detail with reference to a specific embodiment. It is obvious, however, that those skilled in the art can make modifications and alternations to the above-mentioned embodiment without departing from the scope of the present invention.

[0075]

The above description of the construction and advantages of the present invention focuses on the case where the wide-band amplifier is mainly applied to voltage amplification during reception by a wireless communication apparatus, but the scope of the present invention is not limited to the above-mentioned case. It goes without saying that the present invention can be likewise realized even if the wide-band amplifier according to the present invention is applied to transmission in wireless communication or to voltage amplification in uses other than wireless communication.

[0076]

In other words, the foregoing description of the present invention has been given for illustrative purposes only, and

the contents described herein are not to be construed in a limitative way. The scope of the present invention is to be understood as defined by the scope of the appended claims.

[Brief Description of Drawings]

[0077]

[Fig. 1]

Fig. 1 is a view showing the construction (conventional example) of a wide-band amplifier according to one embodiment of the present invention.

[Fig. 2]

Fig. 2 is a view showing a pole-zero map in the s-plane of the wide-band amplifier shown in Fig. 1.

[Fig. 3]

Fig. 3 is a view showing a transfer characteristic example of the wide-band amplifier shown in Fig. 1.

[Fig. 4]

Fig. 4 is a view showing a group delay characteristic of the wide-band amplifier shown in Fig. 1.

[Fig. 5]

Fig. 5 is a view showing a construction example in which a common-gate cascode amplifier is applied as a current output amplifier device in the wide-band amplifier shown in Fig. 1.

[Fig. 6]

Fig. 6 is a view showing a construction example in which a common-source cascode amplifier with voltage feedback is applied as a current output amplifier device in the wide-band amplifier shown in Fig. 1.

[Fig. 7]

Fig. 7 is a view showing the construction of a wireless communication apparatus in which the wide-band amplifier shown in Fig. 1 is applied to an LNA.

[Fig. 8]

Fig. 8 is a view showing the construction (conventional example) of a wide-band amplifier constructed by a combination of an amplifier device and a first-order band-pass filter (BPF).

[Fig. 9]

Fig. 9 is a view showing a pole-zero map in the s-plane of the wide-band amplifier shown in Fig. 8.

[Fig. 10]

Fig. 10 is a view showing a transfer characteristic example of the wide-band amplifier shown in Fig. 8.

[Fig. 11]

Fig. 11 is a view showing a group delay characteristic of the wide-band amplifier shown in Fig. 8.

[Fig. 12]

Fig. 12 is a view showing the construction (conventional example) of a wide-band amplifier constructed by a combination of an amplifier device and a second-order band-pass filter (BPF).

[Fig. 13]

Fig. 13 is a view showing a pole-zero map in the s-plane of the wide-band amplifier shown in Fig. 12.

[Fig. 14]

Fig. 14 is a view showing a transfer characteristic example of the wide-band amplifier shown in Fig. 12.

[Fig. 15]

Fig. 15 is a view showing a group delay characteristic of the wide-band amplifier shown in Fig. 12.

[Description of Reference Numerals]

10 ··· wireless communication apparatus

11 ··· antenna

12 ··· band-pass filter (BPF)

13 ··· transmission/reception switch

14 ··· low noise amplifier (LNA)

15 ··· down-converter

16 ··· automatic gain controller (AGC)

17 ··· analog-digital converter (ADC)

18, 21 ··· signal processing circuit (DSP)

22 ··· digital-analog converter (DAC)

23 ··· up-converter

24 ··· power amplifier (PA)

101 ··· input terminal

102 ··· amplifier device

103 ··· parallel coil Lp

104 ··· parallel capacitor Cp

105 ··· resistor RL

106 ··· series capacitor Cs

107 ··· series coil Ls

108 ··· output terminal

201, 301 ··· MOS-FET

202, 402 ··· resistor

203, 303 ··· bias terminal

204, 302, 401 ··· capacitor